REQUEST FOR ACTION (RFA) RESPONSE

GLAST LAT Project
Calorimeter Peer Review **17 – 18 March 2003**

Action Item:	CAL – 010
Presentation Section:	Thermal
Submitted by:	Tom McCarthy

Request: Sidewall thermal analysis - Does the K-composite consider its directional nature in the composite? Was this accounted for in the analysis?

Reason / Comment: This property is different in film direction vs through-epoxy and was not noted in the analysis.

Response: 18 April 2003

Thermal conductivities of the CAL composite material were calculated in the in-plane and transverse directions. These calculations are summarized in the attached technical note, LLR-GLAST-TN-080-A.

The thermal analysis will be re-run accounting for the directional nature of the conductivities. The updated analysis is covered in RFA CAL-014.

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Note Technique / Technical Note

GLAST	*GLAST LAT CAL* *Mechanical Structure*	Ref: GLAST-LLR-TN-080 Issue: A Date: 7 april 2003 Page : 1

Determination of the thermal conductivities of the CAL composite material

SLAC reference :

Change History log

A	7 april 2003	Creation	P.Prat		S. Le Quellec	O. Ferreira
Ind.	**Date**	**Modifications**	**Prepared**	**Checked**	**PA Approval**	**Project Approval**

Dependence of Material Properties upon the Fiber Volume Fraction and the Resin Content

From MIL-HDBK-3F, the expressions for thermal conductivity of a lamina, in three orthogonal directions (one direct. parallel to the fibers and other two directs. perpendicular to the fibers) are:

$$k_{11} = V_f * k_{f11} + (1 - V_f) * k_m$$

and

$$k_{22} = k_m * \frac{k_{f22} * (1 + V_f) + k_m * V_m}{k_{f22} * V_m + k_m * (1 + V_f)}$$

$$k_{33} = k_{22}$$

Where,

$k_{11} = k_L$ = lamina thermal conductivity, parallel to fibers.

k_{22} & $k_{33} = k_T$ = lamina thermal conductivity, perpendicular to fibers and each other.

k_{f11} = fiber thermal conductivity, in the fiber longitudinal direction.
k_{f22} = fiber thermal conductivity, in the fiber transverse direction.
k_m = thermal conductivity of the resin matrix.
V_f = Volume fraction of fiber.
V_m = Volume fraction of matrix.

Each composite wall is constituted of fiber layers of different orientations. Let fibers in layer i be oriented at an angle ?$_i$ with the global x1 axis. The effective conductivities of a stack of layers of the resin and the fiber are given by :

$$k_{11} = k_L \frac{\sum_{i=1}^{N} h_i \cos^2 \theta_i}{\sum_{i=1}^{N} h_i} + k_T \frac{\sum_{i=1}^{N} h_i \sin^2 \theta_i}{\sum_{i=1}^{N} h_i},$$

$$k_{12} = (k_L - k_T) \frac{\sum_{i=1}^{N} h_i \sin \theta_i \cos \theta_i}{\sum_{i=1}^{N} h_i},$$

$$k_{22} = k_L \frac{\sum_{i=1}^{N} h_i \sin^2 \theta_i}{\sum_{i=1}^{N} h_i} + k_T \frac{\sum_{i=1}^{N} h_i \cos^2 \theta_i}{\sum_{i=1}^{N} h_i},$$

$$k_{33} = k_T,$$

Where N is the number of layers and h_i is the thickness of the ith layer.

Calculation of CAL composite conductivities

The longitudinal and transverse thermal conductivities of the TORAY T300 fiber are (source http://www.torayca.com/techref/en/images/fcp02.html):

$k_{f11} = 7.3\ 10^{-3}$ Cal / (cm. s.K) = 3.056 W/(m.K)
$k_{f22} = 1.4\ 10^{-3}$ Cal / (cm. s.K) = 0.586 W/(m.K)

The conductivity of epoxy is :

$k_m = 0.2$ W/(m.K)

The fraction volume of fiber and epoxy are:

$V_f = 0.55$
$V_m = 0.45$

So, the longitudinal and transverse thermal conductivities of an unidirectional fiber composite laminate are:

$k_L = 1.77$ W/(m.K)

$k_T = 0.348$ W/(m.K)

For the walls constituted of the same number of layers of 2 perpendicular fiber orientations, the in-plane and transverse conductivities are:

$k_{11} = k_{22} = (k_L + k_T)/2 = 1.06$ W/(m.K) ˜ 1 W/(m.K)

$k_{12} = 0$

$k_{33} = k_T = 0.348$ W/(m.K) ˜ 0.35 W/(m.K)

For the walls constituted of the same number of layers of 4 fiber orientations (0°, 90°, +45°, -45°), the in-plane and transverse conductivities are the same as above.

Conclusion

Thus, for the CAL thermal simulation , we will assumed the 2 following in-plane (k_{LC}) and transverse (k_{TC}) conductivities:

$k_{LC} = 1$ W/(m.K)

$k_{TC} = 0.35$ W/(m.K)